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Highway Noise Barrier Options:

Q.E.W. East of Cawthra Road

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ABSTRACT

The Cawthra to Dixie Road section of the QEW is being used to determine noise barrier suitability for situations involving service roads and narrow freeways. Two parallel barriers are proposed between the express lanes and service roads on either side of the highway. The barriers are to be installed atop existing New Jersey walls.

This report evaluates alternative barrier heights, alignments and types, such as inclined and absorptive barriers. A rather limited performance is predicted since:

a) The existing New Jersey wall already serves as a noise barrier of low height.
b) Additional traffic sound reflections may arise after barrier construction.
c) Relatively high sound levels from service road traffic will not be shielded by the proposed barriers.
d) The adjacent backyards are well set back and already protected by houses. Thus, non-acoustical benefits such as reduced salt spray, increased privacy and the like, will likely be absent.

The following basic barrier types were evaluated:

a) vertical sound reflective barriers,
b) vertical sound absorptive barriers assuming different absorption levels, and
c) inclined barriers assuming different sound absorption levels.

The maximum available barrier height of 5 m above pavement is recommended. Various alignment termini are suggested as well. Of the barrier types examined, vertical barriers partially sound absorptive on all surfaces are favored. In this case, the commercial product known as Durisol is suitable because of its absorption properties, durability and availability.

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1/ INTRODUCTION

This report was prepared as an acoustical design advice for noise barrier sites QEW 31 and QEW 32. These sites have been chosen as a test area to determine the possible attenuation and public acceptance of opposing noise barriers located between narrow freeways and heavily travelled service roads. The project is a part of the Ministry's current provincial noise barrier retro-fit program.

The objective of this report is to present the results of acoustical evaluation of different barrier alternatives and, based on these results and other factors such as cost, materials available, and aesthetics, to recommend the optimal barrier height, alignment and type.

The proposed barrier location is along both sides of the QEW, east of Cawthra Road. At this location the QEW has six traffic lanes; three in each direction. On both sides of the QEW there are two-lane service roads. The terrain is flat, gently sloping towards the south (Lake Ontario). Figure 1 shows the general barrier setting. Also shown in Figure 1 are alternative barrier alignments analysed and receiver locations used for sound level calculations.

Construction of a noise barrier at this site had been anticipated during the 1977 reconstruction. Thus, New Jersey walls, separating the QEW from the service roads, were designed to serve also as a foundation for a noise barrier.

The height of the New Jersy walls ranges from 0.8 to 1.2 m. Using a 3 m column spacing, the maximum barrier height above the New Jersey walls is limited to 4 m. Consequently, the maximum total barrier height evaluated was 5 m above the pavement elevation.

2/ EXISTING CONDITIONS

2.1/ Traffic Conditions

Sound levels emitted by traffic on service roads will not be attenuated by the proposed noise barriers. Moreover, if the barriers are sound reflective on the service road side, they would also reflect sound from the service road traffic back to the community and thus amplify it. The photographs in Figures 2 and 3 illustrate this point by showing site overview with vehicles on both the QEW and the service roads.

In order to evaluate relative sound level contributions of the QEW traffic and the service road traffic, a 12-hour traffic classification survey was conducted on April 29, 1981.

The results of the survey indicate a considerable time variation in the proportion of traffic using the QEW and the service roads (see Figure 4). Depending on the time period, the South Service Road traffic volumes represent about 15 to 28% of the eastbound QEW traffic. The North Service Road traffic volumes represent about 12 to 16% of the westbound QEW traffic.

In addition to the variation in traffic volumes, there is also a significant time variation in the percentage of trucks and a difference in the truck percentages observed on North and South Service Roads (see Figure 5). The percentage of trucks on the North Service Road is several times higher than that on the South Service Road. During the period from 9:00 to 10:00 it even exceeds the truck percentage on the QEW itself.

The acoustical effectiveness of barriers will depend on the vehicle distribution (in terms of volume, truck percentage and speed) between the QEW lanes and the service road lanes. The vehicle distribution depends, of course, on the time period involved. The barrier effectiveness will be most compromised during the periods when the proportion of cars and trucks on the service roads is high. For example, this situation can occur for north-side receivers during the period from 9:00 to 10:00.

To avoid the need for calculating barrier performance for different time periods, average traffic volumes during the 12-hour survey period were used (Table 1). This is a departure from the standard procedure of using traffic volumes based on the level of service "C". The use of traffic volumes based on the level of service "C" would have increased the overall sound levels by about 3 dBA and would have affected calculated barrier attenuations. At any rate, it would have been difficult to quantify freeway and service road traffic contributions realistically.

2.2/ Sound Levels

Sound levels were calculated using a standard highway noise prediction computer program [1]. The predictions provided by this program have been found to be in close agreement with measured sound levels and with measured barrier attenuations [2, 3]. The computer program was also used to calculate the effect of multiple reflections as described in [4].

The existing (before barrier construction) sound levels are given for individual receivers in Tables A1 to A3. The average sound levels for typical residential areas are given in Table 2.

Since the sound levels due to the service road traffic cannot be reduced by barriers, the relative contribution of service road traffic and QEW traffic is important. For receivers unshielded by houses, the average sound level due to service road traffic is predicted as being 67 dBA on the north side and 64 dBA on the south side. These sound levels would remain unchanged even if the contribution of the QEW traffic were completely eliminated. Overall, for receivers unshielded by houses, the North Service Road traffic is predicted to contribute an additional 1.5 dBA to the sound levels produced by the QEW traffic only. The corresponding value for the South Service Road traffic is 0.7 dBA. The contribution of the service road traffic diminishes with the distance from the QEW and is about 0.5 to 0.3 dBA for receivers shielded by two or more rows of houses.

These results take into account the existence of the New Jersey walls which already provide some shielding. For example, the closest backyards (i.e. receivers shielded by one row of houses) on the north side receive about 3.5 dBA attenuation while the corresponding backyards on the south side receive about 1.5 dBA attenuation due to the existing New Jersey walls.

2.3/ Non-Acoustical Benefits

Social surveys, conducted to assess subjective performance of four different noise barriers, concluded that residents perceived the non-acoustical benefits of noise barriers to be as significant as the sound attenuation itself [7, 8]. The non-acoustical benefits perceived by residents included reduction in salt spray, dirt, dust, fumes and litter as well as increased privacy and added protection from transients. Since the proposed barrier is already separated from the "adjacent" backyards by a service road, front yards and houses, non-acoustical benefits may not be present at this site.

3/ RESULTS OF ACOUSTICAL ANALYSIS

A number of different barrier alternatives varying in terms of height, alignment and barrier types (such as inclined and sound absorptive barriers) were evaluated. To simplify the analysis, the major factors (height, alignment and barrier type) are discussed separately. However, these factors act jointly to determine sound levels in a community. Also, for clarity, results are generally presented as averages for several similar types of receiver locations.

3.1/ Effect of Barrier Height

Table 2 presents average sound attenuations predicted for different barrier heights and for varying amounts of receiver shielding from houses. In this table, a fully sound absorptive barrier is assumed, as the relative effect of difference in barrier height would not change with the presence or absence of sound reflections. Receivers unshielded by houses have an average predicted existing sound level of 70.3 dBA on the south side and 72.8 dBA on the north side. The difference reflects varying road to receiver distances as well as varying car and truck volumes on adjacent service roads.

All barrier heights evaluated yielded more predicted attenuation for the south side than for the north side, regardless of receiver locations. This may be attributed to three factors:

a) Existing shielding from the approximately 1.2 m high north New Jersey wall exceeds that of the 0.8 m high south New Jersey wall.
b) The north side of the site slopes up and the south side slopes down, relative to the highway, diminishing effective barrier height on the north side and enhancing it on the south side.
c) The heavy truck volume on the north service road is approximately twice that of its southern counterpart.

As expected, 5 m is the most effective barrier height for both sides of the highway yielding an average of 6.0 dBA attenuation for southern receivers shielded by one row of houses and an average of 3.1 dBA, for the comparable northern receivers. The corresponding figures for a 3 m high barrier are 3.5 dBA south side and 0.6 dBA north side.

3.2/ Effect of Termini Options

Tables 3a to 3d present results of proposed termini examined for a 5 m high barrier. The effect of other possible options can be assessed based on this information.

North-West Section

A north-west terminus from F easterly (see Table 31a) yields the largest average attenuation of 2.6 dBA. Locating the barrier immediately adjacent to the QEW in this area is not practicable and would not provide higher attenuation since the service road traffic would still remain unshielded. The remaining barrier options yield results quite similar to those predicted for the option from F easterly with the exception of receivers 34, 35, 37 and 38.

North-East Section

Extending the barrier from K to L and combining it with a roadside terminus at I yields marginally better results than ending it at J alone (see Table 3B). Note that the barrier extension from K to L shields receivers 49 and 50 significantly more than would an extension to I or J only. Beyond this, little difference in attenuation results from options at this section.

South-East Section

A south-easterly terminus at D alone yields minimal attenuation for receivers 26 to 29 (see Table 3C). Extending the alignment from E westerly is the only option which shields both receivers 28 and 29. However, this option does sacrifice some attenuation for receivers 26 and 27 relative to extension O to P combined with a roadside terminus at D.

Along the south service road, between Odgen Avenue and Applewood Road, the residents have themselves erected makeshift barriers. The data reported herein may be applied to such an option whereby the south side barrier on the New Jersey wall would end at the pedestrian crosswalk and then shift to the south sidewalk (replacing the makeshift barriers). East of Applewood Road it would again return to the New Jersey alignment (Figure 1).

South-West Section

At the south-west section of the site, terminating the barrier at A generates virtually identical results to those predicted for extension M to N combined with a roadside terminus at C (Table 3D). However, these options are little better than termini at B and C. In fact, only receivers 2 and 4 would encounter any significant difference between any options investigated for the area.

Termini Selection

The selection of barrier termini depends on benefit and cost. Possible indifference towards termini may result from the rather similar average attenuation predicted for each section's options (see Tables 3a to d). However, closer scrutiny reveals that individual receivers are often significantly affected by specific options. To maximize acoustical benefit, a barrier extending from F to I including K to L as well as a barrier running from A to E is recommended. As barriers perpendicular to the QEW may intrude upon private property, should F to I including K to L be impracticable, option F to S is recommended.

3.3/ Effect of Different Barrier Systems

Table 4 presents average attenuations predicted for different barrier systems necessitated by the parallel barriers at the site. In all cases, a 5 m height is assumed to exist between pavement surface and barrier top. The vertical barrier systems analyzed were:

A) Fully sound absorptive surfaces on both sides of either barrier. A sound absorption coefficient $\alpha = 1.0$ was assumed. This system of barriers would completely eliminate both the sound reflections from the QEW and those from the service roads. However, achieving complete sound absorption may be overly difficult and expensive.

B) Sound reflective surfaces on both sides of either barrier for which a sound absorption coefficient $\alpha = 0.05$ applies. Typically, this is the case for steel or untreated concrete barriers.

C) All barrier surfaces partially sound absorptive. A sound absorption coefficient $\alpha = 0.70$ was used in this case since it is appropriate for the commercial product known as Durisol. Appendix B details its calculation.

D) Partially sound absorptive surfaces on the insides, or QEW sides, of the barriers. This may be accomplished with Durisol on the inner surfaces only and with concrete on the remaining surfaces.

Further analysis involved inclining the north and south barriers by 5° away from the QEW. This degree of inclination was based upon recommendations given in [5]. Figure C1 in Appendix C provides details of image source construction under these circumstances. The inclined barrier alternatives involved:

E) Sound reflective surfaces (α = 0.05) on both sides of either barrier.

F) Partially sound absorptive surfaces (α = 0.70) on the outside, or receiver side, and sound reflecting surfaces on the remaining barrier sides (α = 0.70).

G) All barrier surfaces partially sound absorptive (α = 0.70).

To ensure that absorption and inclination barrier qualities are being singularily examined, the averages in Table 4 are based on locations unaffected by termini options. The fully sound absorptive system (A) is an ideal standard for comparison with the other options. Of all systems, it provides the highest attenuation. Naturally, the highly sound reflective surface on all barrier sides (B) provides lowest attenuation. Specifically, the average sound attenuation for receivers shielded by one row of houses was reduced from 6 dBA on the south side for system (A) to 3.8 dBA for system (B). Similarily, on the north side, it was reduced from 2.9 to 1.0 dBA. The results of the other options are somewhere between these two extremes.

The difference in performance between partially sound absorptive barriers on all sides (C) and barriers partially absorptive on the inside only (D) is about 0.5 dBA. Thus they are quite similar in performance. Inclined barriers generally provide less attenuation than do conventional vertical barriers with all surfaces partially sound absorptive (C). However, inclined barriers with partially sound absorptive surfaces on all sides (G) perform slightly better than vertical barriers with the same surface characteristics (C).

Analysis revealed that 10° inclined barriers would not improve upon the attenuation from their 5° counterparts as the reflections reaching receivers 1.2 m above ground would not be changed.

4/ BARRIER STRUCTURES AND MATERIALS

Any structural solution depends on connecting barrier columns to existing steel plates on top of H-beams in the New Jersey concrete wall, i.e. on having a connection with sufficient bending moment capacity. Concrete or fibreglass barrier columns must have shoes or special receptacles to enable such connection.

Absorptive wall panels are readily available in the form of Durisol. Durisol would be removed from the ground by the height of the New Jersey wall, and should be durable due to very moderate water and salt spray exposure.

Absorptive panels of other materials have yet to be developed. A possible alternative may be hollow panels of fibreglass, perforated on both sides, with a solid zig-zag core filled with sound absorptive fibreglass pads wrapped in soft plastic film.

The effective sound transmission loss (ΔT) for thin gauge steel barriers is of the order of 19 to 20 dBA [6]. Maximum values of geometric insertion losses (ΔB-ΔT) is at least 11.5 dBA. This means that the maximum degradation of barrier insertion loss for steel barriers is less than 0.3 dBA, whereas for concrete and fibreglass barriers, there is no such degradation.

5/ SUMMARY AND RECOMMENDATIONS

1) The predicted sound attenuation is rather limited at this site for the following reasons:
   a) shielding provided by the existing New Jersey walls
   b) relatively high sound levels from service road traffic (up to 3.5 dBA on the north side) which will not be reduced by the proposed barriers
   c) the presence of parallel barriers which will likely result in multiple sound reflections.
2) Unconventional solutions such as sound absorptive and inclined walls are necessitated since conventional sound reflective barriers, even of the maximum available 5 m. height, would provide limited attenuation. An average attenuation of 3.8 dBA would be provided by a conventional solution for adjacent south side backyards, while 1.0 dBA would be provided for their north side counterparts.
3) Moreover, due to the large set back of adjacent backyards, non-acoustical benefits associated with noise barriers, such as reduced salt spray and increased privacy will probabely be nonexistant at this site.
4) The recommended noise barrier alignment (Figure 1) is;

   South Side: from A to E

   North Side: from F to I plus K to L or alternatively, from F to J.

5) To achieve a noticeable attenuation, at least a 5 m high vertical barrier with sound absorptive surfaces is recommended. Durisol panels supported by vertical steel columns could achieve this effect. This would provide an average south side adjacent backyard attenuation of 5.4 dBA and a north side backyard attenuation of 2.5 dBA.
6) A similarly well performing alternative, consisting of barriers inclined away from the express lanes and absorptive on all surfaces, may be considered.

REFERENCES

[1] B.A. Kugler, D.E. Commins and W.J. Galloway "Highway Noise, a Design Guide for Prediction and Control," National Cooperative Highway Research Program Report 174, Transportation Research Board, Washington D.C., 1976.

[2] May, D.N., "Noise Barrier Attenuation - Highway 401 south side, Dixon Rd. to Kipling Ave., Toronto," Report 77-AC-09, Research and Development Division, Ministry of Transportation and Communications, Ontario, November 1977.

[3] Hajek, J.J., "Noise Barrier Attenuation - Highway 401 North Side East of Avenue Road, Toronto," Report 80-AC-03, Research and Development Branch, Ministry of Transportation and Communications, Ontario, 1980.

[4] Hajek, J.J., "Performance of Parallel Highway Noise Barriers - Yonge St. to Bayview Ave., Toronto," Report 80-AC-01, Engineering Research and Development Branch, Ministry of Transportation and Communications, Ontario, 1980.

[5] Hajek, J.J. and Kwan, L., "The Effects of Parallel Highway Noise Barriers," Report AE-81-03, Research and Development Branch, Ministry of Transportation and Communications, Ontario, January 1981.

[6] Jung, F.W., "Traffic Noise Barrier Design for Sound Transmisssion," Report AE-81-01, Research and Development Branch, Ministry of Transportation and Communications, Ontario, 1981.

[7] Kornets, J. and Sharratt, K., "Highway Noise Barriers: A Review of Non-Acoustical Effects," Ontario Ministry of Transportation and Communications, 1979.

[8] O'Grady, J.P., "Environmental Effects of Freeway Noise Barriers," Paper presented at the annual meeting of the Canadian Acoustical Asssociation, Montreal, Quebec, Oct. 1980.

Table 1: Traffic Data Used For Analysis

Facility	No. of Vehicles Per Hour			Traffic Flow Speed, km/h		
	Cars	Medium Trucks	Heavy Trucks	Cars	Medium Trucks	Heavy Trucks
QEW Westbound Express	3413	170	195	100	100	90
QEW Eastbound Express	3527	168	187	100	100	90
Entrance Ramp to QEW Westbound from Cawthra Road Northbound	150	10	5	40	40	40
South Service Road	849	22	4	50	50	50
North Service Road	478	22	8	50	50	50
Exit Ramp from QEW Westbound to Cawthra Road	600	14	24	50	50	40
Entrance Ramp from Cawthra Road Northbound to QEW Eastbound	446	37	31	60	60	50
Cawthra Road Both Directions	937	70	23	60	60	40

Table 2: Effect of Barrier Height

(For Receivers Unaffected by Termini Options)

(Assuming Fully Sound Absorptive Barrier Surfaces)

Amount of Receiver Shielding by Houses / Side of QEW	Sound Level Prediction Before Barrier Construction Leq	Average Sound Level Attenuation, Leq, for Barrier Height		
		3 m Above Pavement	4 m Above Pavement	5 m Above Pavement
	North South	North South	North South	North South
Receivers Unshielded By Houses	72.8 70.3	0.5 2.8	1.2 3.5	1.8 4.3
Receivers Shielded By One Row Of Houses	64.3 66.5	0.6 3.5	1.9 5.0	2.8 6.0
Receivers Shielded By Two or More Rows of Houses	59.5 61.4	0.6 2.9	1.4 4.6	2.0 5.9

Notes: Detail data are presented in Tables 1A to 3A.

Table 3a: Effect of Termini Options (5 m High Barrier)
North-West Section

Receiver Number	Sound Level Prediction Before Barrier Construction, Leq	Sound Level Reduction for Termini Option, Leq		
		From F Easterly	From G Easterly	From H Easterly
32	63.5	0.5	0.0	0.0
33	66.5	1.0	0.0	0.0
34	64.0	4.0	1.5	1.0
35	62.5	4.0	2.0	1.0
36	56.5	1.0	1.0	0.5
37	60.0	4.0	3.0	2.0
38	64.5	3.5	3.5	2.0
39	73.0	2.0	2.0	2.0
40	62.5	3.5	3.5	3.0
41	64.5	3.0	3.0	3.0
average	63.8	2.6	1.9	1.4

Table 3b: Effect of Termini Options (5 m High Barrier)
North-East Section

Receiver Number	Sound Level Prediction Before Barrier Construction, Leq	Sound Level Reduction for Termini Option, Leq		
		From I Westerly Including K to L	From I Westerly	From J Westerly
44	65.5	2.5	2.5	2.5
45	62.5	3.0	2.0	2.5
46	72.5	1.5	1.5	1.5
47	64.5	2.5	1.5	2.5
48	65.0	1.5	0.5	2.0
49	69.0	9.5	1.5	6.5
50	74.0	7.5	2.5	5.5
51	67.5	0.5	0.5	1.0
average	67.6	3.6	1.6	3.0

Table 3c: Effect of Termini (5 m High Barrier)
South-East Section

Receiver Number	Sound Level Prediction Before Barrier Construction, Leq	Sound Level Reduction for Termini Option, Leq.		
		From D Westerly	From D Westerly Including O to P	From E Westerly
22	69.0	7.5	7.5	7.5
23	62.5	6.5	7.0	7.0
24	68.0	7.5	8.5	8.0
25	73.0	7.5	8.0	8.0
26	68.5	1.0	7.5	5.0
27	67.0	0.5	5.5	5.0
28	62.5	1.0	2.0	5.0
29	60.5	0.0	0.0	2.0
average	66.4	3.9	5.7	5.9

Table 3d: Effect of Termini (5 m High Barrier)
South-West Section

Receiver Number	Sound Level Prediction Before Barrier Construction, Leq	Sound Level Reduction for Termini Option, Leq			
		From A Easterly	From B Easterly	From C Easterly	From C Easterly Including M to N
1	72.5	3.0	3.0	2.0	2.0
2	66.5	2.5	1.0	0.5	3.5
3	64.5	3.0	3.0	2.5	3.5
4	61.5	2.5	1.0	0.5	2.0
5	73.5	3.0	3.0	3.0	3.0
6	67.0	5.0	5.0	4.0	4.5
average	67.6	3.2	2.7	2.1	3.1

Table 4: EFFECT OF DIFFERENT BARRIER SYSTEMS (5 m ABOVE PAVEMENT)

(For Receivers Unaffected by Termini Options)

Amount of Receiver Shielding By Houses / Side of QEW	Sound Level Prediction Before Barrier Construction Leq	Average Sound Level Attenuation, Leq, For Barrier System						
		Fully Sound Absorptive On Both Sides, α=1.0 A	Sound Reflective On Both Sides, α=0.05 B	Partially Sound Absorptive On Both Sides, α=0.70 C	Partially Sound Absorptive On Inside Only, α=0.70 D	5° Inclined Sound Reflective On Both Sides, α=0.05 E	5° Inclined Partially Sound Absorptive On Receiver Side Only, α=0.70 F	5° Inclined Partially Sound Absorptive On Both Sides, α=0.70 G
	North South	North South	North South	North South	North South	North South	North South	North South
Receivers Unshielded By Houses	72.8 70.3	1.8 5.2	0.5 3.4	1.2 4.6	0.7 4.0	0.6 3.9	1.0 4.4	1.4 4.8
Receivers Shielded By One Row of Houses	64.3 66.5	2.9 6.0	1.0 3.8	2.5 5.4	2.0 4.9	1.9 4.8	2.4 5.3	2.6 5.7
Receivers Shielded By Two Or More Rows Of Houses	59.5 61.4	2.0 5.9	0.0 3.2	1.3 5.2	1.1 5.0	1.1 5.0	1.2 5.1	1.5 5.4

Note: Detail data are presented in Table A4

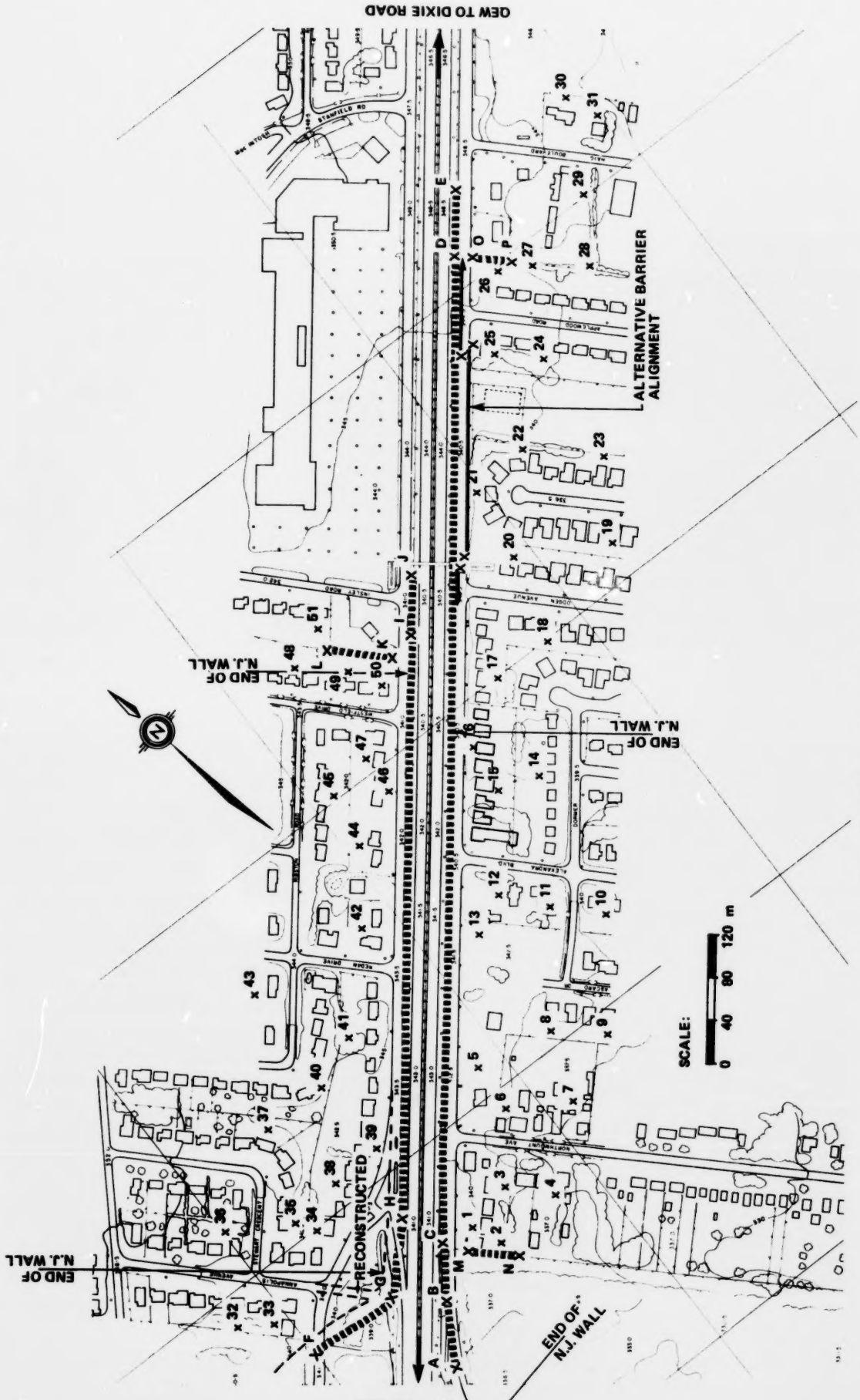

Figure 1/ QEW, Cawthra to Dixie Roads – General Setting

Figure 2/ Site Overview Eastward from the Pedestrian Overpass

Figure 3/ North Service Road and Q.E.W. Westbound

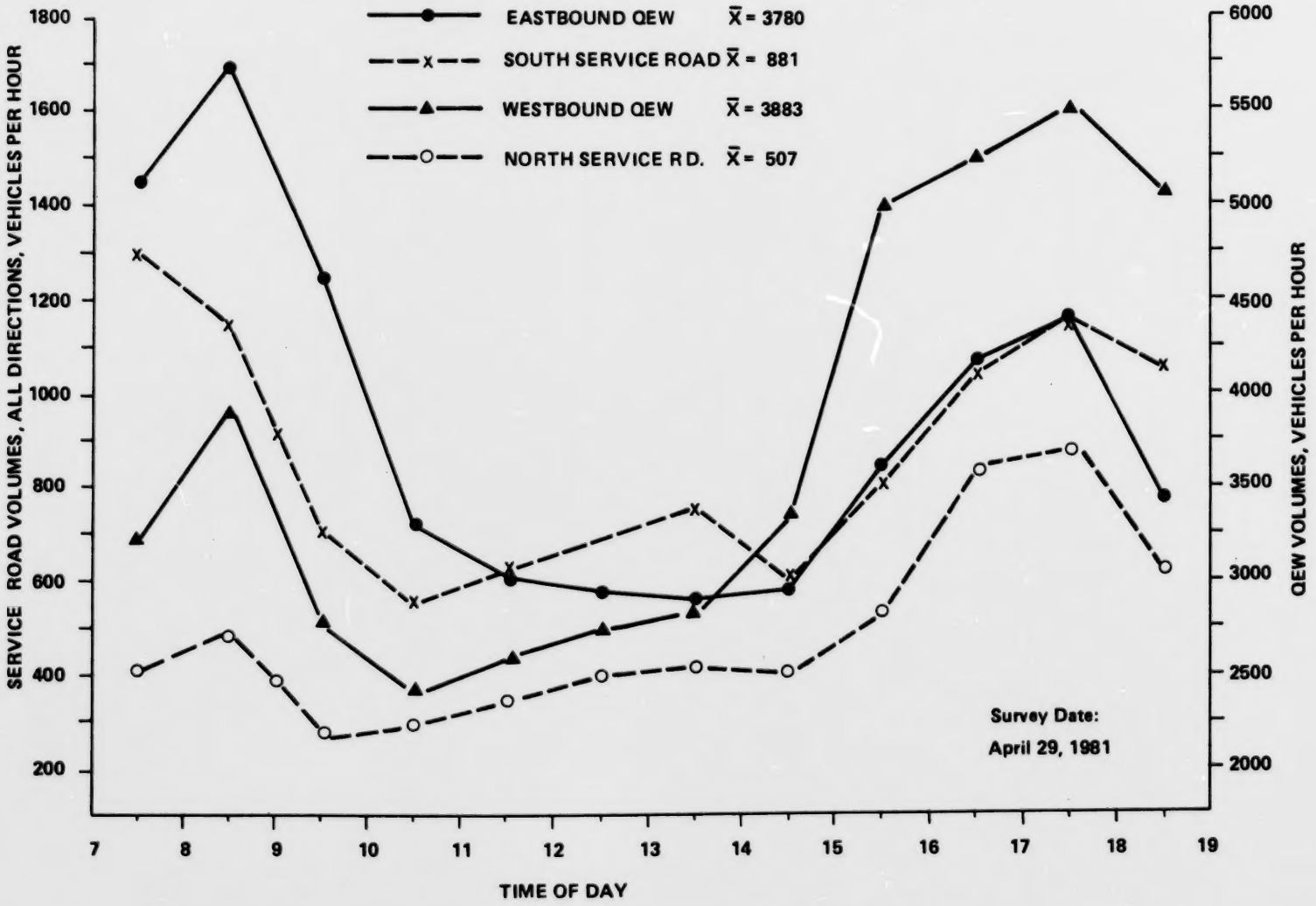
EASTBOUND QEW $\bar{X}$ = 3780
SOUTH SERVICE ROAD $\bar{X}$ = 881
WESTBOUND QEW $\bar{X}$ = 3883
NORTH SERVICE R.D. $\bar{X}$ = 507
SERVICE ROAD VOLUMES, ALL DIRECTIONS, VEHICLES PER HOUR
QEW VOLUMES, VEHICLES PER HOUR
TIME OF DAY
Survey Date:
April 29, 1981

Figure 4/ Hourly Total Traffic Volumes, QEW, Between Cawthra and Dixie Roads

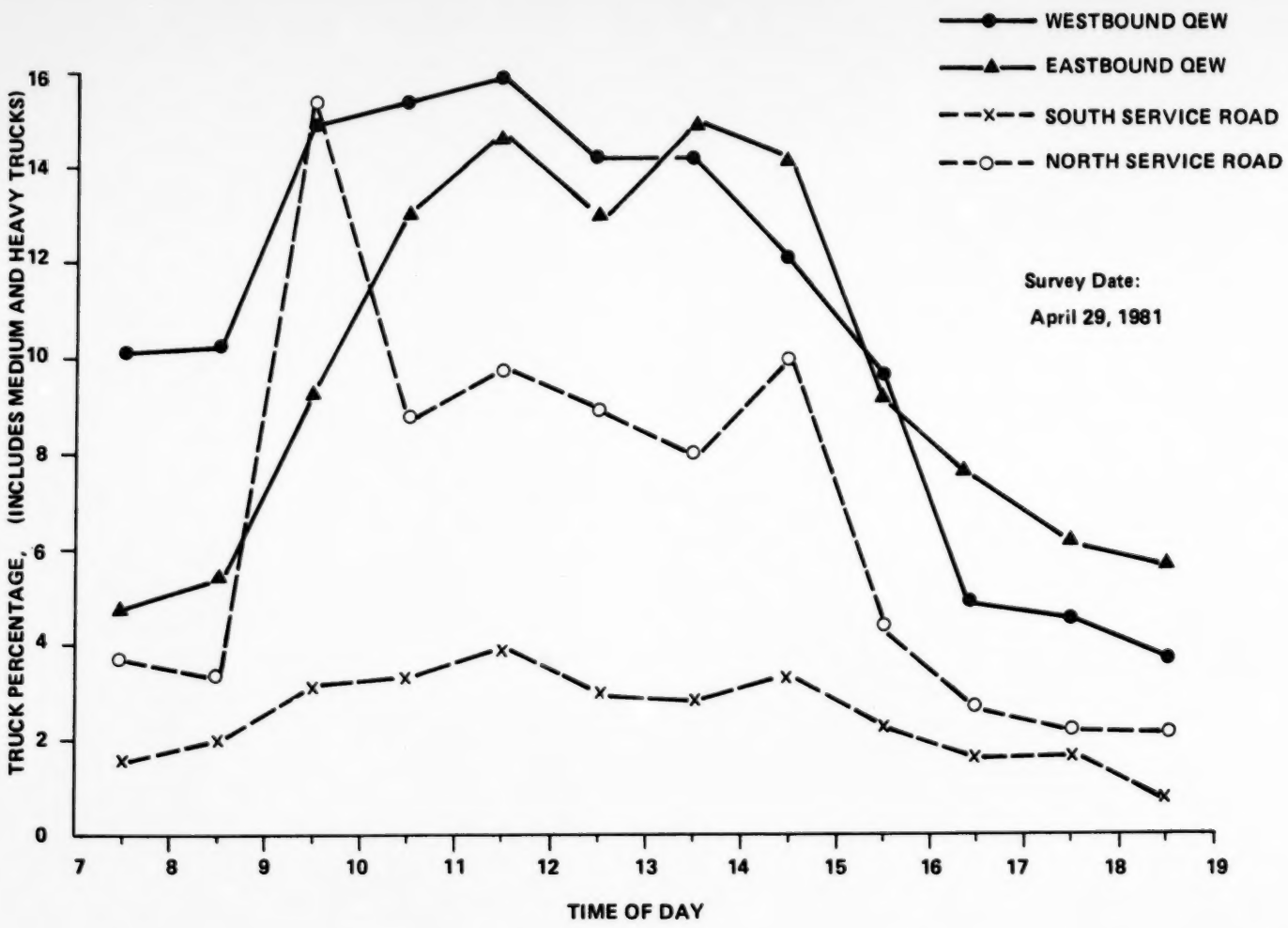

Figure 5/ Variation in Traffic Flow Composition

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APPENDIX A

Table A1 : SOUND LEVEL PREDICTIONS FOR UNSHIELDED RECEIVERS

(Fully Sound Absorptive Barrier on Both Sides)

RECEIVER NUMBER[1]	SOUND LEVEL PREDICTION BEFORE BARRIER CONSTRUCTION Leq[2]	SOUND LEVEL ATTENUATION, Leq, PREDICTED FOR BARRIER OPTION[3]					
		AtoE at4m	AtoE at5m	BtoD at5m	CtoD MtoN OtoP at5m	AtoE at3m	CtoD at5m
S O U T H S I D E							
1	72.5	2.5	3.0	3.0	2.0	1.5	2.0
5	73.5	2.5	3.0	3.0	3.0	1.5	3.0
6	67.0	3.5	5.0	5.0	4.5	2.0	4.0
12	68.0	4.0	5.5	5.5	5.5	2.0	5.5
13	70.0	2.5	3.5	3.5	3.5	1.0	3.5
16	73.0	6.5	8.5	8.5	8.5	4.5	8.5
21	76.0	6.5	NA	7.0	NA	5.5	7.0
25	73.0	7.0	8.0	7.5	8.0	6.0	7.5
average	71.2	4.0	5.2	5.1	5.0	3.0	5.1
		FtoJ at4m	FtoJ at5m	GtoI at5m	HtoI KtoL at5m	FtoJ at3m	
N O R T H S I D E							
39	73.0	1.5	2.0	2.0	2.0	0.5	
46	72.5	1.0	1.5	1.5	1.5	0.5	
50	74.0	5.0	5.5	2.5	7.5	3.5	
average	73.2	2.5	3.0	2.0	3.7	1.5	

NOTES: 1) Receivers are 1.2 m above ground.

2) Assumes the presence of existing New Jersey walls.

3) Barrier heights are relative to pavement elevation.

APPENDIX A

Table A2: SOUND LEVEL PREDICTIONS FOR RECEIVERS SHIELDED by ONE ROW of HOUSES

(Fully Sound Absorptive Barrier on Both Sides)

RECEIVER NUMBER[1]	SOUND LEVEL PREDICTION BEFORE BARRIER CONSTRUCTION Leq[2]	SOUND LEVEL ATTENUATION, Leq, PREDICTED FOR BARRIER OPTION[3]					
		AtoE at4m	AtoE at5m	BtoD at5m	CtoD MtoN OtoP at5m	AtoE at3m	CtoD at5m
SOUTH SIDE							
2	66.5	2.0	2.5	1.0	3.5	1.0	0.5
3	64.5	2.5	3.0	3.0	3.5	1.0	2.5
8	65.5	4.0	5.5	5.5	5.5	2.5	5.5
11	63.5	4.0	5.0	5.0	5.5	2.0	5.0
14	64.5	5.0	6.0	6.0	6.5	3.5	6.0
15	66.0	4.0	5.0	5.0	5.0	3.5	5.0
17	68.5	6.0	7.0	7.0	7.0	4.5	7.0
18	64.0	6.0	7.5	7.5	7.5	4.5	7.5
20	69.5	6.0	7.0	7.0	7.0	4.5	7.0
22	69.0	6.5	7.5	7.5	7.5	4.5	7.5
24	68.0	7.0	8.0	7.5	8.5	5.0	7.5
26	68.5	4.0	5.0	1.0	7.5	3.5	1.0
27	67.0	4.5	5.0	0.5	5.5	4.0	0.5
30	67.0	0.0	NA	0.0	0.0	0.0	0.0
average	66.1	4.4	5.7	4.8	5.2	3.1	4.5
		EtoJ at4m	FtoJ at5m	GtoI at5m	HtoI KtoL at5m	FtoJ at3m	
NORTH SIDE							
33	66.5	1.0	1.0	0.0	0.0	0.0	
34	64.0	3.0	4.0	1.5	1.0	1.5	
35	62.5	3.0	4.0	2.0	1.0	1.5	
38	64.5	2.5	3.5	3.5	2.0	1.5	
40	62.5	2.5	3.5	3.5	3.0	1.0	
41	64.5	2.0	3.0	3.0	3.0	0.5	
42	66.0	1.5	2.5	2.5	2.5	0.5	
44	65.5	1.5	2.5	2.5	2.5	0.5	
45	62.5	1.5	2.5	2.0	3.0	0.0	
47	64.5	2.0	2.5	1.5	2.5	0.5	
49	69.0	5.5	6.5	1.5	9.5	4.0	
average	64.7	2.4	3.2	2.1	2.7	1.0	

1) Receivers are 1.2 m above ground.

2) Assumes the presence of existing New Jersey walls.

3) Barrier heights are relative to pavement elevation.

APPENDIX A

Table A3: SOUND LEVEL PREDICTIONS FOR RECEIVERS SHIELDED by TWO or MORE ROWS of HOUSES

(Fully Sound Absorptive Barrier on Both Sides)

RECEIVER NUMBER[1]	SOUND LEVEL PREDICTION BEFORE BARRIER CONSTRUCTION Leq[2]	SOUND LEVEL ATTENUATION, Leq, dBA PREDICTED FOR BARRIER OPTION[3]					
		AtoE at4m	AtoE at5m	BtoD at5m	CtoD MtoN OtoP at5m	AtoE at3m	CtoD at5m
S O U T H	S I D E						
4	61.5	1.5	2.5	1.0	2.0	0.5	0.5
7	61.0	3.5	4.0	3.5	4.0	1.5	3.5
9	61.5	4.0	5.5	5.5	5.5	2.0	5.5
10	61.0	4.0	5.5	5.5	5.5	2.5	5.5
19	61.0	6.0	7.5	7.5	7.5	4.5	7.5
23	62.5	5.5	7.0	6.5	7.0	4.0	6.5
28	62.5	4.5	5.0	1.0	2.0	3.5	1.0
29	60.5	1.5	2.0	0.0	0.0	1.5	0.0
31	65.0	0.0	0.0	0.0	0.0	0.0	0.0
average	61.8	3.4	4.3	3.4	3.7	2.2	3.3
		FtoJ at4m	FtoJ at5m	Gtol at5m	Htol KtoL at5m	FtoJ at3m	
N O R T H	S I D E						
32	63.5	0.5	0.5	0.0	0.0	0.5	
36	56.5	0.5	1.0	1.0	0.5	0.0	
37	60.0	2.5	4.0	3.0	2.0	1.5	
43	58.0	2.0	2.5	2.0	2.5	0.5	
48	65.0	1.5	2.0	0.5	1.5	1.0	
51	67.5	0.5	1.0	0.5	0.5	0.0	
average	61.7	1.2	1.8	1.2	1.2	0.6	

1) Receivers are 1.2 m above ground.

2) Assumes the presence of existing New Jersey walls.

3) Barrier heights are relative to pavement elevation.

APPENDIX A

TABLE A4: EFFECT OF DIFFERENT BARRIER SYSTEMS (5 m ABOVE PAVEMENT)

(For Receivers Unaffected by Terminl Options, South Side)

Receiver Number[1]	Barrier Systems (all 5 m above pavement)							
	Sound Level Prediction Before Barrier Construction L_{eq}[2]	Fully Sound Absorptive On Both Sides, α=1.0 A	Sound Reflective On Both Sides, α=0.05 B	Partially Sound Absorptive On Both Sides, α=0.70 C	Partially Sound Absorptive On Inside Only, α=0.70 D	5° Inclined Sound Reflective On Both Sides, α=0.05 E	5° Inclined Partially Sound Absorptive On Receiver Side Only, α=0.70 F	5° Inclined Partially Sound Absorptive On Both Sides, α=0.70 G
		RECEIVERS UNSHIELDED BY HOUSES						
5	73.5	4.0	3.0	3.5	3.5	3.5	3.5	3.7
6	67.0	5.0	2.5	4.0	3.0	3.0	4.0	4.2
12	68.0	5.5	2.5	4.5	3.5	3.5	4.5	5.0
13	70.0	3.5	1.5	3.0	2.0	2.0	2.5	3.1
25	73.0	8.0	7.5	8.0	8.0	7.5	7.5	8.0
average	70.3	5.2	3.4	4.6	4.0	3.9	4.4	4.8
		RECEIVERS SHIELDED BY ONE ROW OF HOUSES						
3	64.5	3.0	1.0	2.5	1.5	1.5	2.5	3.0
8	65.5	5.5	2.5	4.5	4.0	4.0	4.5	5.0
11	63.5	5.0	2.0	4.5	4.0	3.5	4.0	4.5
14	64.5	6.0	2.5	5.5	5.0	5.0	5.5	5.5
15	66.0	5.0	2.0	4.0	3.5	3.5	4.0	4.5
17	68.5	7.0	5.5	6.5	6.5	6.5	6.5	6.5
18	64.0	7.5	4.0	6.5	6.0	6.0	6.5	7.0
20	69.5	7.0	5.5	6.5	6.0	6.0	6.5	7.0
22	69.0	7.5	7.0	7.5	7.0	7.0	7.5	7.5
24	68.0	8.0	6.5	7.5	7.0	7.0	7.5	7.8
26	68.5	5.0	3.0	3.5	3.0	3.0	3.0	4.0
average	66.5	6.0	3.8	5.4	4.9	4.8	5.3	5.7
		RECEIVERS SHIELDED BY TWO OR MORE ROWS OF HOUSES						
7	61.0	4.0	1.0	3.0	3.0	3.0	3.0	3.5
9	61.5	5.5	2.0	4.5	4.0	4.0	4.5	5.0
10	61.0	5.5	2.0	4.5	4.0	4.0	4.5	5.0
19	61.0	7.5	5.0	7.0	7.0	7.0	7.0	7.0
23	62.5	7.0	6.0	7.0	7.0	7.0	6.5	6.5
average	61.4	5.9	3.2	5.2	5.0	5.0	5.1	5.4

1) Receivers are 1.2 m above ground.

2) Assumes the presence of existing New Jersey walls.

Appendix B

The average sound absorption coefficient for Durisol α_A = 0.70, was calculated using the following procedure:

1. Frequency dependent sound absorption coefficients for a complete panel in a free standing position, given in Figure B1 were used.
2. A typical freeway traffic noise spectrum (20 m from edge of pavement)was:
   i) "A" weighted in the frequency range of 125 to 5000 Hz, and
   ii) its overall A-weighted sound level was calculated.
   iii) The spectrum obtained in (i) was reduced in the frequency range of 125 to 5000 Hz, using a formula:
   $\Delta dB = 10 \log (1 - \alpha)$, where
   ΔdB = reduction due to sound absorption coefficient α
   iv) Overall A-weighted sound level obtained in (iii) was calculated.
3. A difference between the overall A-weighted sound levels obtained in (i) and (iv) was calculated.
4. Average sound absortion coefficient for Durisol α_A was obtained using a formula:

$$\alpha_A = 1 - 10^{X/10}$$

where:

X = difference in overall A-weighted sound levels obtained in Step 3.

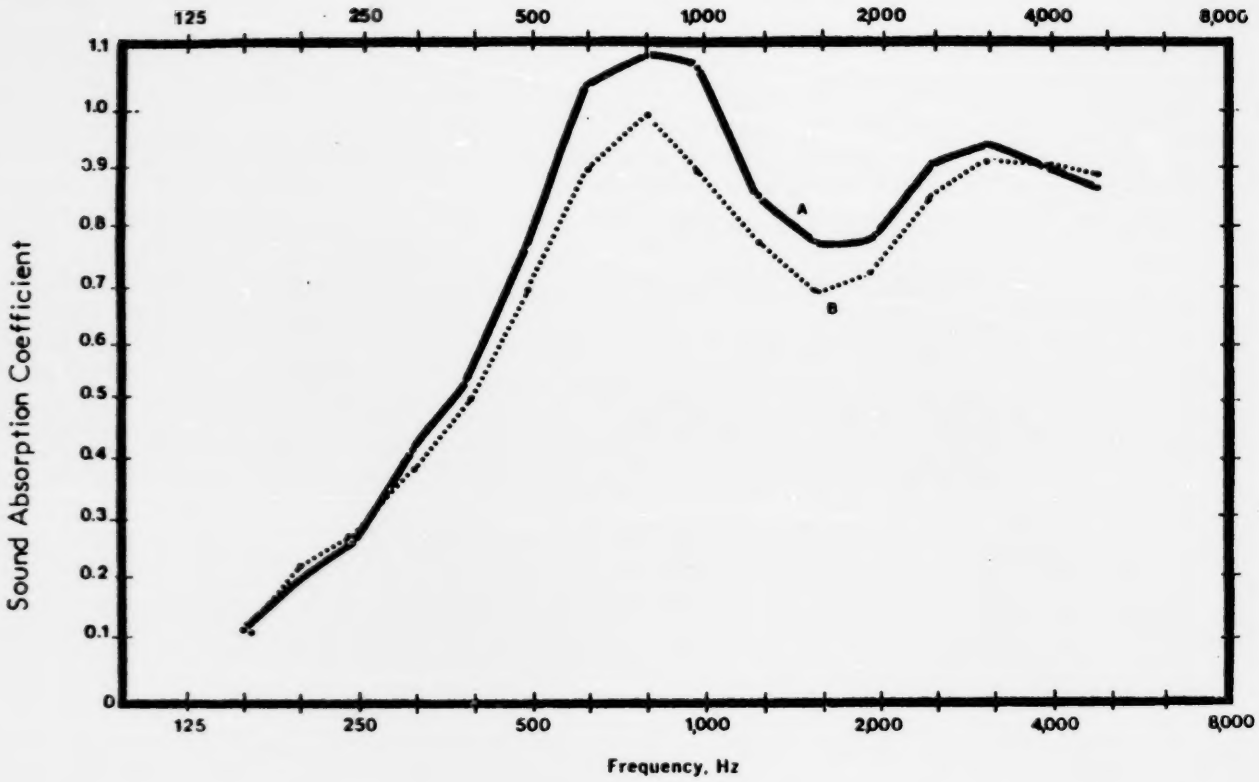

Figure B1, Absorption Coefficient of Durisol (complete panel) Measured in the Reverberant Room. A - laid on floor; B - free standing position.

Source: Behar, A., "Limitations in the Measurement of the Sound Absorption Coefficient on Materials for Highway Noise Barriers. Acoustics and Noise Control in Canada, Volume 8, No. 4, Oct. 1980, p. 28.

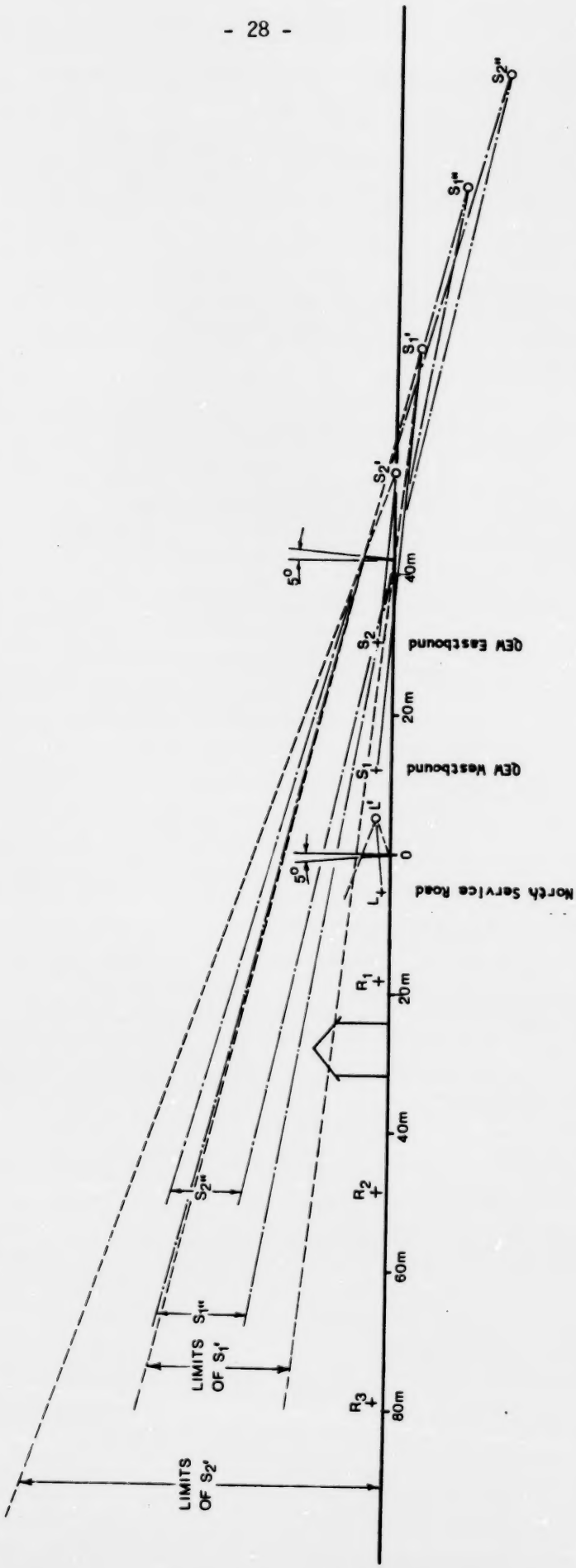

Figure C1/ Construction of Image Sources for 5° Inclined Barriers